Advancements in Wastewater Treatment: Sustainable Solutions and Technological Innovation

Mridani Tripathi, Supriya Yadav, Smriti Ojha, Pratik Kumar Vishwakarma*

Department of Pharmaceutical Science & Technology, Madan Mohan Malaviya University of Technology, Gorakhpur, Uttar Pradesh

*Corresponding author's e-mail: pratikkumar.kumar13@gmail.com

doi: https://doi.org/10.21467/proceedings.161.18

ABSTRACT

Water contamination is a serious problem that endangers both aquatic and terrestrial life. Ecosystem balance is upset, Biochemical Oxygen Demand (BOD) levels are off, and eutrophication results, all of which have disastrous effects on the environment. Effective wastewater management and treatment are essential to resolving this issue to save lives and safeguard water resources. The term "water management" refers to a group of procedures used to collect, treat, and reuse wastewater. Phase separation, sedimentation, filtration, and oxidation are common traditional wastewater treatment techniques. Recent technological developments have, however, produced creative answers that boost productivity and support sustainability. The Microbial Fuel Cell (MFC) is one such innovation. MFCs capture the energy contained in wastewater sludge and use biological processes to produce electricity. Along with treating the wastewater, this also offers a sustainable energy source. The Automated Variable Filtration (AVF) system, which uses cutting-edge filtering methods to remove pollutants and impurities from wastewater, is another innovation. It enables effective and automatic management of the filtration procedure, leading to better water quality. Another useful tool for wastewater treatment is nanotechnology. It is possible to more efficiently remove contaminants from water by using nanomaterials with special features. These substances, such as nano filters and nanocomposites, have better catalytic and adsorption properties, increasing the effectiveness of treatment. Another prominent approach is thermal hydrolysis, which uses heat and pressure to degrade organic materials in wastewater. By facilitating the conversion of organic waste into biogas and utilizing batch and EXELYIS technologies, this procedure lessens the negative environmental effects of wastewater treatment. These cutting-edge technologies offer long-term approaches to wastewater treatment, promoting the growth of eco-friendly lifestyles and minimizing water waste. We can efficiently manage and treat wastewater by putting these cutting-edge techniques in place, protecting water resources, and reducing the possibility of environmental disasters brought on by water pollution.

Keywords: Wastewater, Ecosystem, Phase separation, EXELYIS, Sustainable

1 Introduction

All aquatic and human life are faced with a daunting task due to water pollution, which also has a negative impact on ecosystems and threatens the delicate balance of nature [1]. Wide-ranging effects of water pollution include eutrophication, algal blooms, biomagnification, changes in Biochemical Oxygen Demand (BOD) levels, and many other problems. The management and treatment of wastewater are crucial in reducing these dangers and guaranteeing the survival of life [2]. Water management requires an all-encompassing strategy that includes wastewater collection, treatment, and reuse. The goal is to transform wastewater into effluent that can be recycled for useful purposes or brought back into the water cycle with little negative environmental impact. Additionally, it comprises the safe disposal of pharmaceutical waste, which entails managing medicines carefully and preventing their infiltration into the water supply. Water management works to maintain valuable water resources and safeguard the environment by solving these

Proceedings DOI: 10.21467/proceedings.161; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-965621-8-2

issues [3]. Phase separation, sedimentation, filtration, and oxidation are just a few of the crucial elements that make up traditional wastewater treatment systems. These procedures are made to clean up wastewater and make it safe to discharge back into the environment by removing toxins and impurities. However, the development of novel methods that improve the effectiveness and sustainability of wastewater treatment has been made possible by technological breakthroughs. Microbial Fuel Cell (MFC) technology is one such example. MFCs use biological processes to clean wastewater and produce power at the same time [4]. They use the energy created when microorganisms consume wastewater sludge, producing charged electrons as a consequence. This encourages sustainable practices by enabling efficient wastewater treatment and offering a renewable energy source. Another significant development in wastewater treatment is Automatic Variable Filtration (AVF). This system uses cutting-edge filtering methods to effectively filter pollutants and other impurities out of wastewater. AVF provides precise control over the filtering process through the use of automation and real-time monitoring, which improves water quality and treatment effectiveness [5]. Another useful tool for wastewater treatment is nanotechnology. Nanomaterials have special qualities that make them very good at eliminating impurities from water. Nanofilters and nanocomposites, for example, have improved catalytic and adsorption properties that make it possible to remove pollutants effectively while also enhancing the treatment process as a whole [6]. A further important technique that has become popular in wastewater treatment is thermal hydrolysis. In this method, organic debris in wastewater is broken down using heat and pressure. It lessens the environmental effect of wastewater treatment while enabling the conversion of organic waste into biogas, a renewable energy source [7]. Two thermal hydrolysis technologies that have been created to enhance the treatment process are batch and EXELYIS. These cutting-edge technologies offer effective and environmentally friendly wastewater treatment methods, promoting the growth of environmentally friendly behaviors and minimizing water waste. We can efficiently manage and treat wastewater by incorporating these developments into the methods used to treat it, protecting water resources and reducing the possibility of environmental disasters brought on by water pollution [8]. The safe and effective management of pharmaceutical waste is just as important as the treatment of wastewater. Unused, expired, or leftover pharmaceuticals are referred to as pharmaceutical waste because improper disposal of them can have a negative impact on both human health and the environment. Pharmaceutical waste can enter water systems through improper disposal, poisoning water supplies, and endangering aquatic ecosystems and human populations [9]. Sustainable and creative methods have been created to solve this problem by reducing the quantity of pharmaceutical waste produced and promoting its safe treatment. These methods include a variety of tactics including public awareness campaigns, take-back initiatives, and the adoption of safe disposal practices. We can greatly lessen the environmental effects associated with pharmaceutical waste by educating the general people on the significance of ethical pharmaceutical waste disposal and by offering accessible and easy collection places [10].

1.1 Wastewater effects

Wastewater contamination of water poses a serious hazard to the ecosystem (shown in Figure 1.0) and has substantial negative repercussions [11]. It has negative effects and upsets the sensitive ecosystems' equilibrium. BOD level fluctuations, eutrophication, algal blooms, biomagnification, and other environmental dangers are a few of these impacts. The negative impacts of wastewater on the environment must be effectively managed and treated to be reduced [12]. The following are some of the main consequences of wastewater.

1.2 Algal Blooms

Detrimental algal blooms (HABs) can arise as a result of wastewater discharge. Algal blooms are defined as the quick and voluminous growth of algae, which can release toxins that are harmful to both aquatic life and people [13]. Wide-ranging effects of these blooms include the death of fish, disruption of leisure activities, contamination of drinking water reservoirs, and negative effects on the health of marine life. Without being properly treated, wastewater that is particularly high in nutrients like nitrogen and phosphorus and enters aquatic bodies can encourage the formation of algae. The abundance of nutrients makes it possible for algae to grow quickly and generate massive blooms. Certain kinds of algae inside these blooms can create toxic substances that are dangerous to aquatic life and even people, such as cyanotoxins [14]. There are several effects of algal blooms. Fish deaths can happen when too many algae blooms reduce the amount of oxygen in the water, suffocating fish and other aquatic life. Algal blooms can also prevent people from participating in outdoor activities like swimming, boating, and fishing because of their unsightly look and potential health hazards from the poisons they release. It also poses a serious risk to human health if drinking water sources are polluted with algal toxins, necessitating expensive treatment procedures to guarantee the security of the water supply [15]. Additionally, some marine creatures, including shellfish and other filter-feeding animals, can build up algal toxins in their tissues, rendering them toxic for ingestion and harmful to those who do. To reduce the negative consequences of algal blooms brought on by wastewater discharge, it is essential to manage and treat wastewater properly. The excessive growth of algae in receiving water bodies may be prevented by implementing effective treatment techniques, which can eliminate or greatly reduce nutrients and other contaminants present in wastewater [16]. Algal bloom monitoring and early identification can also aid in the start of necessary activities to lessen their effects and safeguard ecosystems and human health.

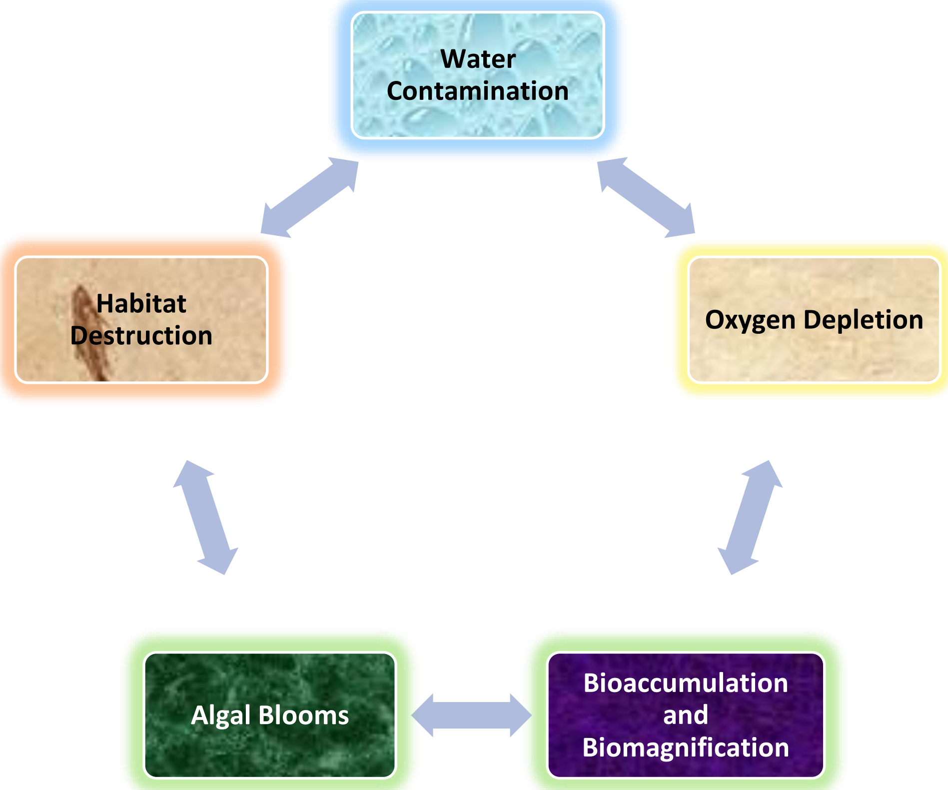

Figure 1: *Wastewater Effect on Ecosystem*

1.3 Biomagnification

The phenomenon known as "biomagnification" occurs when the concentration of pharmaceuticals or dangerous chemicals, such as pesticides or heavy metals, gradually rises at increasing levels within a food chain or food web [17]. The biomagnification of chemicals like dichloro-diphenyl-trichloroethane (DDT), polychlorinated biphenyls (PCBs), mercury, arsenic, and other comparable compounds is an example of this process. Agriculture-related pollutants such as pesticides, fertilizers, and other pollutants are the major causes of biomagnification. We'll use the biomagnification of DDT in an aquatic food chain as an example. DDT levels in creatures at lower trophic levels, including zooplankton, may be as high as 0.04 parts per million (ppm) [18]. The content of DDT in their tissues rises when the DDT-containing species are eaten by higher trophic-level organisms, including tiny fish. As larger fish eat the smaller fish, the process repeats, resulting in a higher concentration of DDT. In top predators like eagles, the concentration of DDT can eventually rise to levels as high as 5 ppm. The features of these dangerous drugs are the cause of this behavior. They can build up in an organism's tissues and are resistant to destruction. Lower trophic level creatures absorb and store these chemicals when they are exposed to them [19], [20]. Due to the cumulative impact, higher trophic level species amass a higher concentration of the drug when they devour more of these infected creatures. Ecosystems and the creatures that reside within them are seriously threatened by biomagnification. These dangerous compounds can cause serious health problems and reproductive concerns in top predators as their concentration rises the food chain. Additionally, it may have a domino effect on the ecosystem's general stability and balance. The use of pesticides and other dangerous compounds is strictly regulated and controlled, and sustainable farming practices are implemented as part of efforts to reduce biomagnification [21], [22]. We can reduce the danger of biomagnification and safeguard the well-being of species and ecosystems by minimizing the number of pollutants we release into the environment and implementing ecologically friendly alternatives.

1.4 Eutrophication

A natural or man-made process called eutrophication causes water bodies to become more loaded with minerals and nutrients. There is an abundance of flora in the water due to the oversupply of nutrients that encourage plant and algae development [23]. However, human activities that speed up this process can have a negative impact on the water quality and general well-being of aquatic ecosystems. The release of pharmaceutical waste, such as outdated drugs and chemicals, can worsen the negative impacts of eutrophication. The introduction of extra nutrients and pollutants by pharmaceutical waste into water bodies promotes the development of plants and algae known as an "algal bloom," this out-of-control growth can produce thick mats of vegetation on the water's surface, preventing sunlight from reaching submerged plants and lowering the water's oxygen content [24]. Eutrophication caused by the discharge of pharmaceutical waste has several negative effects. First off, an overabundance of algae and plants can reduce the quality of the water, making it harder for light to pierce the surface and affecting the survival of underwater animals. Furthermore, when the algae and plants deteriorate and die, bacteria devour the organic material, absorbing a significant quantity of dissolved oxygen in the process [25]. Fish and other oxygen-dependent creatures may die as a result of this oxygen deprivation due to hypoxic or anoxic circumstances. Additionally, the contamination of the environment by harmful compounds is another risk posed by pharmaceutical waste in water bodies. Drugs and chemicals can linger in the water, perhaps killing aquatic life and upsetting the ecosystem's delicate balance. When consumed by people who eat infected fish or other aquatic animals, these toxins can also enter the food chain and impact creatures at higher trophic levels [26]. Adequate waste management procedures must be put in place in order to reduce the effects of pharmaceutical waste on eutrophication. This involves safely managing and treating chemical waste, properly disposing of outdated pharmaceuticals, and educating people about the possible environmental effects of inappropriate waste disposal [27]. Additionally, by enhancing wastewater treatment procedures, pharmaceutical waste may be cleaned of toxins and nutrients before being dumped into bodies of water, reducing the amount of eutrophication. We can lessen the negative consequences of eutrophication, safeguard water quality, and maintain the well-being of aquatic ecosystems by addressing the problem of pharmaceutical waste discharge and adopting proactive steps to decrease nutrient input into water bodies [28].

1.5 Management

Taking all these into account wastewater management is the most concerning area as it ensures the availability of pure water and deals with pharmaceutical wastage. Some traditional wastewater management systems include three stages as shown in Figure 2.

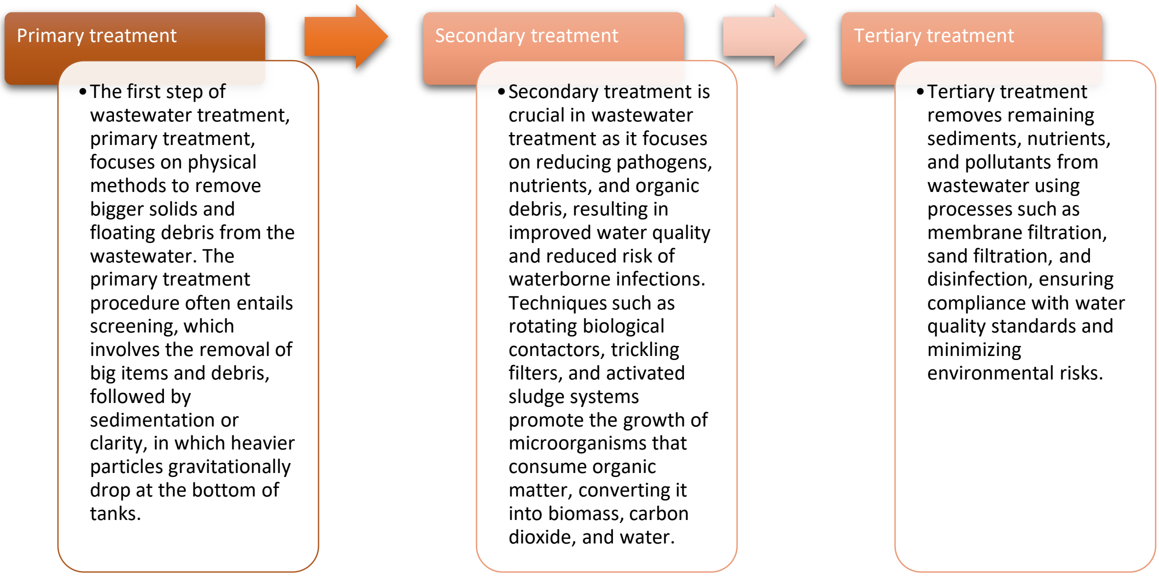

Figure 2: *Indicates the three phases of wastewater treatment.*

2 Recent technologies

To improve the efficiency and sustainability of wastewater treatment, some new technologies are as follows-

2.1 Microbial fuel cell

An innovative technique utilized to handle different pharmaceutical wastes is microbial fuel cells (MFCs). An MFC system uses microorganisms to sequentially transform chemical energy from the oxidation of organic or inorganic molecules into adenosine triphosphate (ATP). This procedure results in the transmission of electrons to a terminal electron acceptor, which generates an electrical current, due to problems with the spread of antibiotic-resistant bacteria and the presence of pharmaceutical substances that might damage aquatic species, the use of MFCs in the treatment of pharmaceutical waste is particularly crucial. Antibiotic residues found in pharmaceutical waste are frequently responsible for the emergence and spread of antibiotic resistance in the environment. Additionally, certain NSAIDs, such as diclofenac, which are frequently discovered in pharmaceutical waste, might have hazardous effects on aquatic creatures, by producing power and using microbes to break down organic chemicals, it offers a sustainable and

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922

ecologically benign method. The bacteria or archaea that are used as microorganisms serve as biocatalysts, transferring electrons from the cathode to the anode to produce an electrical potential difference. It is possible to harness and use this electrical current for a variety of purposes. A potential method for handling pharmaceutical wastes is microbial fuel cells (MFCs). MFCs can efficiently decompose chemical molecules, eliminate pharmaceutical remnants, and fight antibiotic-resistant bacteria by using the metabolic powers of microbes. This resource-conscious strategy makes handling pharmaceutical waste more resource- and environmentally friendly by helping to cleanse wastewater and maybe generating power at the same time.

2.2 Working

A typical microbial fuel cell (MFC) consists of two compartments: the anode and the cathode, separated by a cationic membrane. The anode compartment is where the microbes reside. These microbes metabolize organic compounds, such as glucose, which act as electron donors. During the metabolism of these organic compounds, electrons and protons are generated. The electrons are transferred to the surface of the anode, where they accumulate. Simultaneously, the protons are released into the solution, and from the anode, the electrons flow through an external electrical circuit to reach the cathode compartment. Meanwhile, the protons migrate through the electrolyte and then pass through the cationic membrane to reach the cathode compartment. In the cathode compartment, the electrons and protons are consumed in a reduction reaction with a soluble electron acceptor. This electron acceptor can be substances such as oxygen, hexacyanoferrate, or acidic permanganate. The reduction of these acceptors helps maintain charge balance in the system and completes the electron transfer process. Overall, the MFC operates by facilitating the flow of electrons from the anode to the cathode through the external circuit while allowing the migration of protons through the electrolyte and cationic membrane. This electron flow generates an electric current that can be harnessed for various applications, such as powering electronic devices or contributing to the electrical grid.

2.3 Application

1. Wastewater Treatment: By using microorganisms to degrade organic substances, MFCs may efficiently clean wastewater that contains a lot of organic material. This procedure produces electrical energy as a byproduct in addition to cleaning up contaminants.
2. Sustainable Energy Generation: A sustainable and renewable energy source is possible with MFCs. They can generate power from a variety of organic waste streams, such as industrial waste, food waste, and agricultural waste. Small-scale applications can be powered by this energy, or they can be utilized to support the electrical grid.
3. Remote Power Generation: MFCs are useful for power generation in off-the-grid or isolated areas with limited access to traditional energy sources. In remote locations, they can supply electricity for sensors, watchdog equipment, or low-power applications.
4. Sustainable Agriculture: MFCs might be included in agricultural systems to purify water and recover nutrients. They can lessen the negative effects of nutrient runoff on the environment by capturing and converting nutrients from animal manure into power.
5. Desalination: Desalination procedures can benefit from the integration of MFC technology to increase their effectiveness. MFCs can assist in driving the desalination process and reduce energy requirements by combining them with desalination methods like reverse osmosis or electrodialysis.

Bacteria play a very crucial role in MFC, so it is necessary to discuss various types of microbes used in MFC. These bacteria were further classified as shown in Table 1.

Table 1: Type *of Microbes and Their Functions*

S. No	Microbe Type	Description	Function in MFC
1.	Shewanella spp.	Gram-negative bacteria that can transfer electrons to solid surfaces	Act as electrogenic bacteria, transferring electrons from the microbial metabolism to the anode.
2.	Geobacter spp.	Geobacter species are electrogenic bacteria capable of extracellular electron transfer	They play a crucial role in direct electron transfer and are commonly used in MFCs.
3.	Escherichia coli	Gram-negative bacteria commonly found in the gut of humans and animals	Used in MFC research as a model organism for studying electron transfer mechanisms and biofilm formation.
4.	Pseudomonas spp.	Common Gram-negative bacteria are known for their metabolic versatility	Used in MFCs due to their ability to produce high current densities and tolerance to various environmental conditions.
5.	Bacillus spp.	Gram-positive bacteria with diverse metabolic capabilities	Used in MFCs for their ability to generate electricity and their resistance to extreme environmental conditions.
6.	Clostridium spp.	Anaerobic Gram-positive bacteria that produce electricity through fermentation processes	Used in MFCs for their ability to generate current by utilizing a wide range of organic compounds.
7.	Rhodopseudomonas spp.	Purple non-sulfur bacteria capable of both photosynthesis and respiration	Used in MFCs to harness their ability to transfer electrons from organic matter to the anode.
8.	Mixed cultures	A combination of different microbial species present in natural environments	Often used in MFCs to mimic real-world conditions and enhance the overall performance and stability of the system.

3 Thermal hydrolysis

Thermal hydrolysis is a wastewater treatment process that includes heating and applying pressure to sewage sludge or other moist organic material. Anaerobic digestion, a popular technique for handling organic waste, is intended to be made more efficient and effective through this procedure. Thermal hydrolysis involves heating organic waste or sewage sludge under high pressure. The waste material's structure is disturbed, and complex organic components are broken down by exposure to high pressure and temperature. As a result, during anaerobic digestion, the waste is more readily digestible by microorganisms. The waste's organic substance is released during the heat hydrolysis process, making it easier for microorganisms to degrade it. This results in better biogas generation and more readily available nutrients in the digester. Microorganisms and volatile substances in the waste material can both be reduced by heat hydrolysis. The process's high temperatures and pressures aid in sterilizing the sludge, making it safer for reuse or disposal. In wastewater treatment facilities, heat hydrolysis is a useful method for improving the anaerobic digestion process. It provides advantages including greater energy recovery, improved waste management, and less environmental impact by dissolving complex organic molecules and enhancing biogas generation.

3.1 Working

In the wastewater treatment plant, the raw sewage sludge undergoes a series of steps for further treatment. After the primary and secondary treatment units, the sludge is collected and dewatered to achieve a dry

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922

solids content of 16-18%. This thickened sludge is continuously fed into the pulper, where it is further processed. From the pulper, the warm sludge is continuously fed into the reactors sequentially, ensuring that each reactor contains a sealed batch of sludge. As one reactor fills up, the sludge flows into the next available reactor, maintaining a continuous process. Within the reactor, the sludge undergoes sterilization and hydrolysis to facilitate the breakdown of organic matter. The sterilized and hydrolyzed sludge is then transferred to the flash tank, which operates at atmospheric pressure. From the flash tank, the sludge is cooled in heat exchangers to reach the typical temperature required for anaerobic digestion. Finally, the cooled sludge is fed into the anaerobic digesters, where further treatment and decomposition of organic matter occur.

3.2 Application of thermal hydrolysis

1. The sludge cake has a lower odor.
2. Reduced carbon footprint of the facility, particularly when combined with other water tech services.
3. As the biosolid mass and volume decrease, the residual management cost is lower.
4. Biosolids produced are an effective and low-cost fertilizer.
5. Excess biogas production can be used for sustainable electricity production or grid injection.

4 Automated variable filtration

An easy technique is Automated Variable Filtration (AVF), which filters the influent by having filter media flow downhill as the influent flows upward. This novel method does not require additional steps or freshwater to clean the filter medium. By successfully eliminating pollutants and impurities from the influent, AVF technology offers a cost-effective and environmentally friendly alternative for wastewater treatment. AVF optimizes the filtering process while reducing the need for maintenance and resource usage by using the downward flow of filter material. With less operational complexity and environmental impact than conventional filtering systems, this technology provides wastewater treatment facilities with an affordable and practical alternative.

4.1 Working

Based on a distinct filtering concept, the Automated Variable filtering (AVF) system functions. This system uses a filter bed with granular filter material, with the influent being directed to flow upward through it. Filter medium traps suspended solids, particles, and other impurities when the influent flows through the filter bed, enabling only clean water to pass through. AVF stands out due to its capacity to autonomously regulate the filtering process. The system has sensors and controls that keep track of the influent's pressure and flow rate. The AVF system modifies the flow rate and backwashing cycle based on these readings to improve filtering performance. The system starts a backwashing cycle when the pressure drop across the filter bed crosses a predetermined threshold, signaling that the filter media is beginning to clog. Backwashing involves the flow being reversed so that water is sent through the filter bed at an angle. By doing this operation, the filter media's collected particles are dislodged and removed, restoring its capacity for filtering. In order to reduce water waste, the AVF system efficiently uses the cleansed backwash water by sending it to additional treatment stages like settling tanks or sludge treatment units. The entire water usage is decreased, and sustainable operation is ensured by this closed-loop method. Since the AVF system is made to run constantly, filtering may continue even when backwashing is being done. The Automated Variable Filtration system offers an automated and optimized filtration process for wastewater treatment, which improves the system's efficiency and dependability. AVF improves water quality and sustainability in wastewater treatment facilities by successfully collecting and eliminating impurities and by making optimal use of water resources.

4.2 Application

1. Wastewater Treatment: The treatment of municipal and industrial wastewater uses AVF technology. It successfully purges pollutants, suspended particulates, and other impurities from the influent, enhancing the overall water quality before discharge or re-use.
2. Drinking Water Treatment: AVF systems are used in water treatment facilities to clean and disinfect raw water before it is turned into potable water. It aids in purifying the water supply by removing particles, turbidity, and other contaminants.
3. Stormwater Filtration: Stormwater management systems use AVF technology to treat runoff water and remove contaminants before it is released into water bodies. It aids in safeguarding the integrity of receiving waters and avoiding pollution.

5 Future prospective

In recent years, several innovative technologies have emerged in the field of wastewater treatment and energy recuperation. One such technology is the implementation of CW-MFCs (constructed wetland microbial fuel cells), which have shown promising results in the complex treatment of sewage while simultaneously generating green energy. By reducing the reliance on fossil fuels in traditional treatment processes, CW-MFCs contribute to sustainable and environmentally friendly practices. Additionally, it is crucial to address the issue of overprescribing and overuse of medications in healthcare. To combat this problem, healthcare providers should prioritize prescribing and dispensing only the necessary amount of medication required to treat a patient's condition, thereby minimizing waste and potential adverse effects. Furthermore, advanced oxidation processes (AOPs) have emerged as a highly effective and efficient solution for wastewater treatment. By utilizing chemical and biological agents, AOPs can effectively break down organic pollutants, offering a comprehensive approach when combined with other technologies. These advancements in wastewater treatment and sustainable practices hold great promise for mitigating environmental pollution and fostering a healthier future.

6 Conclusion

Significant improvements in establishing long-term water management strategies have been made as a result of the development of new technology for wastewater treatment. These novel strategies address the urgent problems caused by pharmaceutical waste, water contamination, and resource depletion. By putting these technologies into practice, we can efficiently safeguard both aquatic and terrestrial life, save water, and lessen the impact of environmental disasters. Technologies like microbial fuel cells (MFCs) use biological processes to transform sewage sludge into charged electrons, offering a productive and environmentally friendly approach to treatment. Automated Variable filtering (AVF) systems have transformed the filtering process by increasing water quality, reducing resource use, and optimizing efficiency. Technologies for thermal hydrolysis, such as batch and EXELYIS, provide efficient ways to handle organic waste while maximizing energy recovery to improve the treatment procedure, these new technologies encourage the reusing of treated water, aiding in attempts to save water. They are essential in lowering the number of toxic compounds that are dumped into water bodies, as well as in avoiding eutrophication, biomagnification, and algal blooms. Additionally, by safely managing pharmaceutical waste, these eco-friendly methods limit the development of germs resistant to antibiotics and the discharge of hazardous materials into the environment. To achieve sustainable growth and safeguard our water resources, these innovative technologies must be used in wastewater treatment facilities and water management systems. To maintain the long-term health and sustainability of our water ecosystems, we must prioritize the widespread use of these technologies as we develop and improve them. By adopting these environmentally friendly alternatives, we can build a brighter future where everyone has access to clean water and environmental effects are reduced.

7 Declarations

7.1 Competing Interests

The authors declare no conflict of interest.

7.2 Study Limitations

There are no limitations that significantly affect the research outcome.

7.3 Acknowledgements

We would like to sincerely thank everyone whose contributions were essential to the development of this review paper, "Pharmaceutical Pollution." First of all, we would like to express our profound gratitude to Smriti Ojha for her great help with conducting in-depth literature reviews. Her commitment to detail and methodical approach really enhanced the range and depth of the material. A special thanks to Mridani Tripathi for her skill in writing the manuscript and combining several perspectives to create a compelling story that clarifies the intricacies of pharmaceutical pollution. Pratik Kumar Vishwakarma is deserving of praise for his hard work managing the data analysis and adding important images, which improved the article's impact and clarity. We also thank Supriya Yadav for her continuous support during this project, which has been really helpful in terms of insights and motivation. Finally, we would like to express our gratitude to each and every person for their collaborative efforts, which have shaped this piece and advanced the conversation around pharmaceutical pollution.

7.4 Warning for Hazard

The work does not involve any chemicals, procedures, or equipment with unusual hazards.

7.5 Ethical Approval

Ethical approval is not required for this study.

7.6 Informed Consent

No human or animal subjects were involved in this research; hence no informed consent was obtained.

7.7 Publisher's Note

AIJR remains neutral with regard to jurisdictional claims in institutional affiliations.

How to Cite

Tripathi *et al.* (2023). Advancements in Wastewater Treatment: Sustainable Solutions and Technological Innovation. *AIJR Proceedings*, 158-168. https://doi.org/10.21467/proceedings.161.18

References

[1] I. Bashir, F. A. Lone, R. A. Bhat, S. A. Mir, Z. A. Dar, and S. A. Dar, "Concerns and threats of contamination on aquatic ecosystems," in *Bioremediation and Biotechnology: Sustainable Approaches to Pollution Degradation*, Nature Publishing Group, 2020, pp. 1–26. doi: 10.1007/978-3-030-35691-0_1.

[2] K. K. Kesari *et al.*, "Wastewater Treatment and Reuse: a Review of its Applications and Health Implications," *Water, Air, and Soil Pollution*, vol. 232, no. 5. 2021. doi: 10.1007/s11270-021-05154-8.

[3] P. Zoga, A. Bode, R. Balla, N. Kodhelaj, and S. Kucaj, "Water resources systems planning and management," in *Water Resources Planning and Management*, 2012, pp. 452–457. doi: 10.33107/ubt-ic.2012.67.

[4] G. J. Tsekouras *et al.*, "Microbial Fuel Cell for Wastewater Treatment as Power Plant in Smart Grids: Utopia or Reality?," *Front. Energy Res.*, vol. 10, 2022, doi: 10.3389/fenrg.2022.843768.

[5] E. D. Allen, E. F. Czarra, and L. DeTolla, "Water Quality and Water Delivery Systems," in *Management of Animal Care and Use Programs in Research, Education, and Testing: Second Edition*, CRC Press/Taylor & Francis, 2017, pp. 655–672. doi: 10.1201/9781315152189-28.

[6] M. Anjum, R. Miandad, M. Waqas, F. Gehany, and M. A. Barakat, "Remediation of wastewater using various nano-materials," *Arabian Journal of Chemistry*, vol. 12, no. 8. pp. 4897–4919, 2019. doi: 10.1016/j.arabjc.2016.10.004.

[7] G. Glivin, N. Kalaiselvan, V. Mariappan, M. Premalatha, P. C. Murugan, and J. Sekhar, "Conversion of biowaste to biogas: A review of current status on techno-economic challenges, policies, technologies and mitigation to environmental impacts," *Fuel*, vol. 302, 2021, doi: 10.1016/j.fuel.2021.121153.

[8] K. Obaideen, N. Shehata, E. T. Sayed, M. A. Abdelkareem, M. S. Mahmoud, and A. G. Olabi, "The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline," *Energy Nexus*, vol. 7, p. 100112, 2022, doi: 10.1016/j.nexus.2022.100112.

[9] K. Samal, S. Mahapatra, and M. Hibzur Ali, "Pharmaceutical wastewater as Emerging Contaminants (EC): Treatment technologies, impact on environment and human health," *Energy Nexus*, vol. 6, p. 100076, 2022, doi: 10.1016/j.nexus.2022.100076.

[10] M. Paut Kusturica, M. Jevtic, and J. T. Ristovski, "Minimizing the environmental impact of unused pharmaceuticals: Review focused on prevention," *Frontiers in Environmental Science*, vol. 10. 2022. doi: 10.3389/fenvs.2022.1077974.

[11] L. Lin, H. Yang, and X. Xu, "Effects of Water Pollution on Human Health and Disease Heterogeneity: A Review," *Frontiers in Environmental Science*, vol. 10. 2022. doi: 10.3389/fenvs.2022.880246.

[12] A. J. Englande, P. Krenkel, and J. Shamas, "Wastewater Treatment &Water Reclamation☆," in *Reference Module in Earth Systems and Environmental Sciences*, 2015. doi: 10.1016/b978-0-12-409548-9.09508-7.

[13] P. M. Glibert, "Algal blooms," in *Encyclopedia of Earth Sciences Series*, 2016, pp. 7–16. doi: 10.1007/978-94-017-8801-4_14.

[14] R. P. Rastogi, D. Madamwar, and A. Incharoensakdi, "Bloom dynamics of cyanobacteria and their toxins: Environmental health impacts and mitigation strategies," *Frontiers in Microbiology*, vol. 6, no. NOV. 2015. doi: 10.3389/fmicb.2015.01254.

[15] S. Ge, X. Qiao, X. Zhao, X. Li, and Y. Liu, "Microcystin in source water: pollution characteristics and human health risk assessment," *RSC Adv.*, vol. 11, no. 11, pp. 6415–6422, 2021, doi: 10.1039/d0ra08983d.

[16] N. Abdel-Raouf, A. A. Al-Homaidan, and I. B. M. Ibraheem, "Microalgae and wastewater treatment," *Saudi Journal of Biological Sciences*, vol. 19, no. 3. pp. 257–275, 2012. doi: 10.1016/j.sjbs.2012.04.005.

[17] M. E. Miller, M. Hamann, and F. J. Kroon, "Bioaccumulation and biomagnification of microplastics in marine organisms: A review and meta-analysis of current data," *PLoS ONE*, vol. 15, no. 10 October. 2020. doi: 10.1371/journal.pone.0240792.

[18] A. Alengebawy, S. T. Abdelkhalek, S. R. Qureshi, and M. Q. Wang, "Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications," *Toxics*, vol. 9, no. 3. pp. 1–34, 2021. doi: 10.3390/toxics9030042.

[19] M. Jaishankar, T. Tseten, N. Anbalagan, B. B. Mathew, and K. N. Beeregowda, "Toxicity, mechanism and health effects of some heavy metals," *Interdisciplinary Toxicology*, vol. 7, no. 2. 2014. doi: 10.2478/intox-2014-0009.

[20] K. G. Drouillard, "Biomagnification," *Encycl. Ecol.*, pp. 353–358, Jan. 2018, doi: 10.1016/B978-0-444-63768-0.00377-2.

[21] C. A. Damalas and I. G. Eleftherohorinos, "Pesticide exposure, safety issues, and risk assessment indicators," *International Journal of Environmental Research and Public Health*, vol. 8, no. 5. 2011. doi: 10.3390/ijerph8051402.

[22] A. Sharma *et al.*, "Worldwide pesticide usage and its impacts on ecosystem," *SN Applied Sciences*, vol. 1, no. 11. 2019. doi: 10.1007/s42452-019-1485-1.

[23] M. Le Moal *et al.*, "Eutrophication: A new wine in an old bottle?," *Science of the Total Environment*, vol. 651. pp. 1–11, 2019. doi: 10.1016/j.scitotenv.2018.09.139.

[24] A. S. Nwankwegu *et al.*, "Harmful algal blooms under changing climate and constantly increasing anthropogenic actions: the review of management implications," *3 Biotech*, vol. 9, no. 12. 2019. doi: 10.1007/s13205-019-1976-1.

[25] M. Plöhn *et al.*, "Wastewater treatment by microalgae," *Physiol. Plant.*, vol. 173, no. 2, pp. 568–578, 2021, doi: 10.1111/ppl.13427.

[26] R. Rani, P. Sharma, R. Kumar, and Y. A. Hajam, "Effects of heavy metals and pesticides on fish," in *Bacterial Fish Diseases*, 2022, pp. 59–86. doi: 10.1016/b978-0-323-85624-9.00016-6.

[27] M. M. Begum *et al.*, "Disposal Practices of Unused and Leftover Medicines in the Households of Dhaka Metropolis," *Pharmacy*, vol. 9, no. 2, p. 103, 2021, doi: 10.3390/pharmacy9020103.

[28] D. W. Schindler, S. R. Carpenter, S. C. Chapra, R. E. Hecky, and D. M. Orihel, "Reducing phosphorus to curb lake eutrophication is a success," *Environ. Sci. Technol.*, vol. 50, no. 17, pp. 8923–8929, 2016, doi: 10.1021/acs.est.6b02204.

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922